INSTITUTE OF PHYSICS Joint APP and HEPP Annual Conference (2018)

QED Parton Distribution Functions
(on behalf of the MM(N)HT collaboration)

Ricky Nathvani

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High Energy Physics Department, University College London

Motivation

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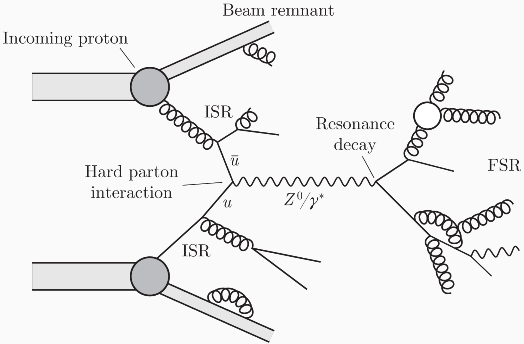

Beam remnant
Incoming proton
ISR
Resonance
decay
FSR
$\bar{u}$
Hard parton
interaction
u
Z^0/γ^*
ISR

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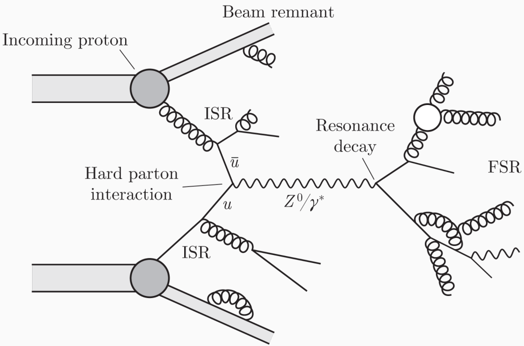

$$\sigma_{pp\to X}^{(N^kLO)} = \Sigma_{a,b} \int x_1 x_2 f_a(x_1)^{(N^kLO)} \hat{\sigma}_{ab\to k}^{(N^kLO)} f_b(x_2)^{(N^kLO)} D(k \to X)$$

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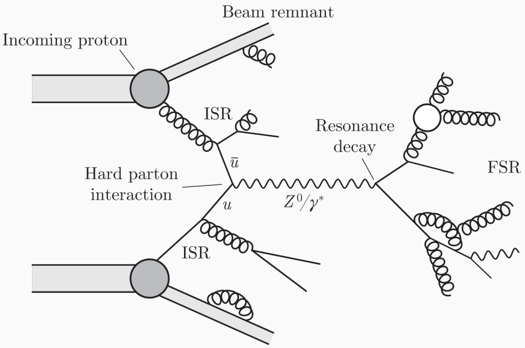

$$\sigma^{(N^kLO)}_{pp\to X} = \Sigma_{a,b}\int x_1 x_2 f_a(x_1)^{(N^kLO)}\hat{\sigma}^{(N^kLO)}_{ab\to k} f_b(x_2)^{(N^kLO)} D(k\to X)$$

Factorisation theorem: Separation of long scale and short scale physics. Introduces a factorisation scal μ_F. Long scale physics $\rightarrow$ Parton Distribution Functions.

Parton Distribution Functions

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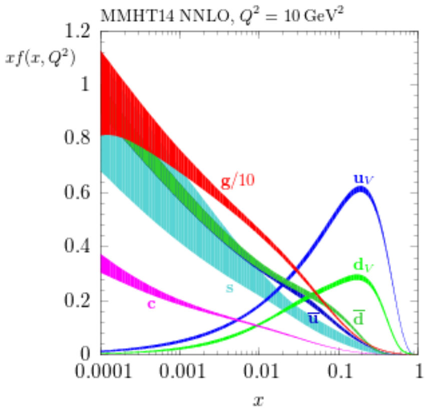
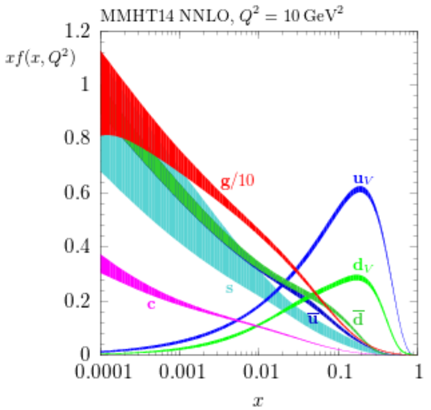


Parton Distribution Functions



Heuristically, PDFs are the momenta distribution of quarks, inside the proton; the internal structure of the proton at high energies. Different distributions at different energy scales.

Why QED?

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- Calculate hard processes to a given order in pQCD.

$$\hat{\sigma} = \hat{\sigma}^{Born}\left(1 + \frac{\alpha_S}{2\pi}\hat{\sigma}^{(1)} + \frac{\alpha_S^2}{2\pi}\hat{\sigma}^{(2)} + \frac{\alpha_S^3}{2\pi}\hat{\sigma}^{(3)} + ...\right)$$

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$\alpha_S^2 \simeq \alpha_{EM} \rightarrow$ Expect QED to become relevant
Introduces the photon as an interacting parton.

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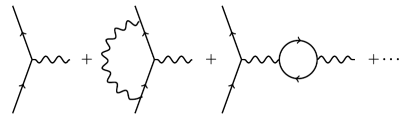
Example: The Electromagnetic coupling constant (and other force couplings)



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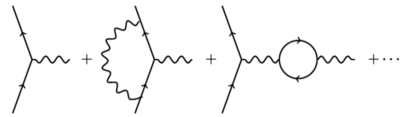
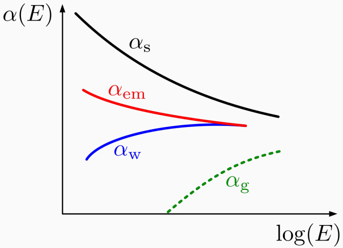


Leads to the running of the coupling constant.



DGLAP

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- PDFs: $f(x, \mu_F)$ loosely, the probability within the proton for a particle (quark, gluon, photon) to carry momentum fraction $0 < x < 1$. We require $\frac{d\sigma}{d\Omega}$'s to be independent of μ_F.

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- **DGLAP equation**:

$$\mu_F \frac{d}{d\mu_F} f_i(x, \mu) = \frac{\alpha_S}{2\pi} \sum_j P_{ij}(\alpha_S(\mu)) \otimes f_j$$

where

$$(f \otimes g)(x) = \int_x^1 \frac{dy}{y} f\left(\frac{x}{y}\right) g(y)$$

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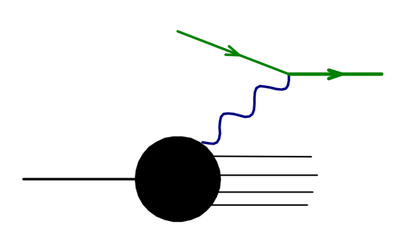
- $\mathbf{P_{ij}}$ calculated at a particular order. Including QED processes introduces a photon. In principle we only need to fit the PDFs at some initial scale Q_0 then use DGLAP to evolve them for all other Q^2 (Scale of hard process).

LUXQED

For the photon, we can express starting distribution $\gamma(x, Q_0 = 1GeV^2)$ in terms of experimentally determined structure functions (ArXiv: 1607.04635, 1607.04266).



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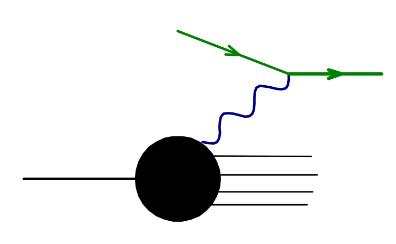
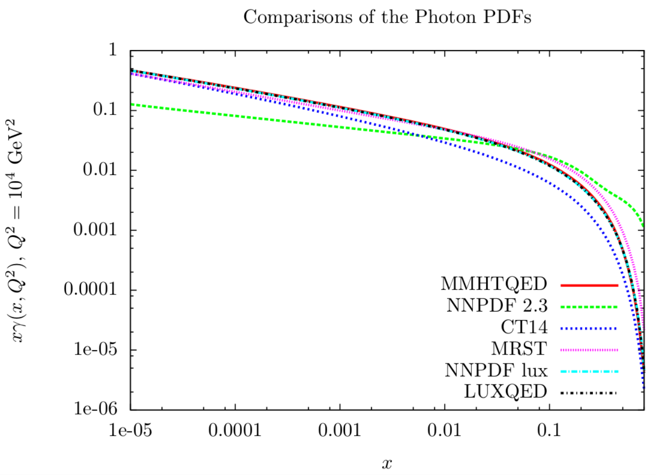


Errors ($\lessapprox 5\%$) are then propagated from measurements of F_2 structure function, which is experimentally well determined from DIS experiments (e.g. HERA).

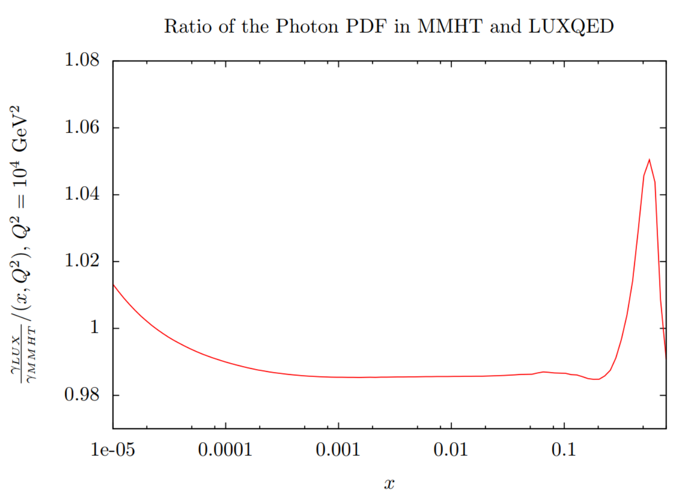
MMHTQED

We have developed an equivalent photon PDF with full QED DGLAP evolution of all partons.



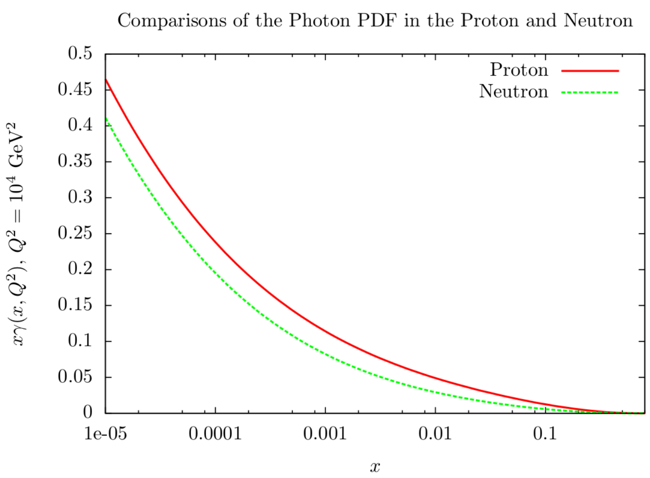
Comparison with LUX

Good agreement with LUXQED.



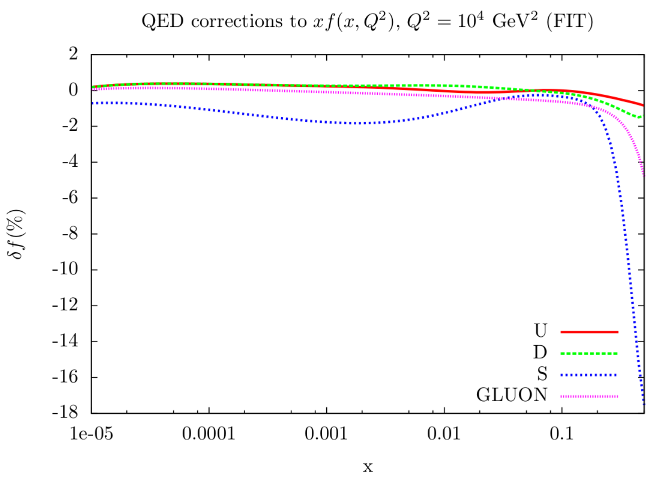
Neutron Photon PDF

We have also produced an equivalent set of Neutron PDFs include an equivalent Neutron Photon PDF.



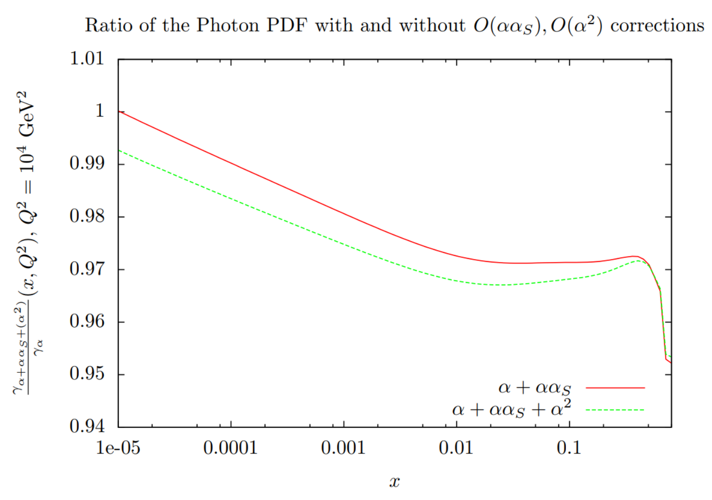
Measured effects on quarks

Calculated the effects of QED on parton momenta within the proton.



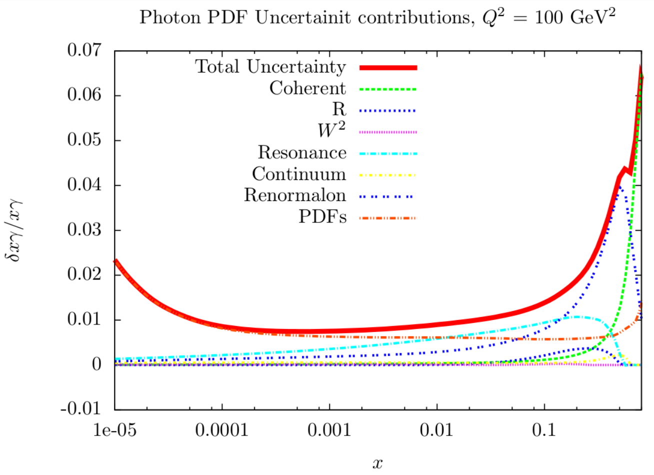
Higher orders

Included mixed order $O(\alpha_S \alpha)$ and $O(\alpha^2)$ corrections.



Uncertainty Contributions

Relative contributions to the photon PDF uncertainty well controlled.



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Anticipated experimental sensitivity to Electroweak correction		
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Top pair production	Total, differential cross sections	$\sim$2%,$\sim$10%

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- Increasing needs on theoretical precision motivate the inclusion of QED as well as QCD in calculations.
- The MMHT group has produced competitive QED partons and investigated their effects.
- To be released later this year.

Thank you for your attention

Any questions?